91602
new 82-10

91-05272/

COMPLIMENTARY COPY
Please Credit Ontario Hydro Research if
Reproduced in Whole or in Part

ontario hydro
research division

To Mr. D.G. Shelton
Station Manager
Lambton TGS

Attn: Mr. D. Hunter

LAMBTON TGS ASH STORAGE AREA - RESULTS OF 1990 FIELD WORK

A. Vorauer

Field work was conducted in the Lambton TGS ash storage area in 1990 for the purpose of confirming some of the assumptions made during slope stability studies conducted in 1989. Activities consisted of: 1) obtaining continuous, undisturbed samples of fly ash for density determinations; 2) installing piezometers to determine and monitor the position of the water table within the ash mound. The bulk density of the fly ash within the storage area was determined to average 90 pcf (1440 kg/m^3) which confirms the assumption made during previous slope stability analyses. The elevation of the water table is at its highest in the southeast quadrant of the disposal area and decreases to the northwest towards Lake Lambton. The water level in the southeast quadrant is higher than the crest of the surrounding clay dyke. This has lead to several small slumping failures of the ash slope along the outside perimeter of the disposal area. Recommendations are made concerning the maximum allowable angle of outside ash slopes, stabilization of the south shore of Lake Lambton and reduction of the water level in the southeast quadrant of the ash disposal area.

1.0 INTRODUCTION

The continued production of fly ash at the Lambton Thermal Generating Station near Sarnia, Ontario, resulted in a need to increase the on-site ash storage capacity. To accommodate the increased volume of fly ash, it was proposed to raise the height of the ash mound to 18 m above grade. The overall stability of this new ash mound was investigated and the results were provided in a previous report/1/.

job	file	date	report no.
43-226-573	843.12	December 10,1990	90-303-K

LEGAL NOTICE

This report was prepared by Ontario Hydro and, while effort has been made to assure the accuracy and applicability of the material contained herein, neither Ontario Hydro nor any person acting on its behalf:

(a) makes any warranty, express or implied with respect to the use of any information, apparatus, method or process disclosed in this report or that such use may not infringe privately owned rights; or

(b) assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method or process disclosed in this report.

The most important finding of this previous investigation was that the critical failure surface for the ash mound was deep-seated, reaching a maximum depth of 25 m below grade. The presence of a relatively weak clay layer (undrained shear strength = 48 kPa) between 17.5 and 27.5 m below grade was the main factor influencing the location of the critical failure surface. Under this condition, the total weight of fly ash acting on the ground surface played an important role in the overall stability of the ash mound. Specifically, the assumed bulk density of ash and the ash mound height had the greatest influence on the magnitude of the safety factor.

Another finding of the previous stability analyses was that the position of the water table within the ash mound was not a critical factor in the overall stability of the mound. However, if the water table were to exit above the toe of the ash slope, localized shallow slope failures could take place.

Two main recommendations were made in the previous report on ash mound stability/1/: i) data must be collected on the distribution of ash bulk densities within the mound before proper limits can be placed on slope heights and angles; ii) water level measurements should be obtained in the vicinity of important ash slopes to help evaluate stability conditions. The following sections will provide the results of a field and laboratory program conducted in the summer of 1990 in an effort to follow-up on these previous recommendations.

2.0 FIELD PROGRAM

The ash disposal area at Lambton TGS occupies 44 ha in the northeast portion of the station property. The top of the ash mound has locally reached a maximum elevation of 203 m.ASL. Lake Lambton, which occupies an area of approximately 7 ha in the northwest corner of the ash disposal area, serves as a collection pond for runoff from the ash mound and from the adjacent coal pile to the west. Two smaller ponds occupy the southwest corner of the disposal area as shown in Figure 1. The elevation contours shown in Figure 1 were based on aerial photos taken in 1987. In the past three years, the 203 m contour has extended significantly to the east beyond the original north-south haul road.

The field work at Lambton TGS was conducted in June, 1990, and consisted of augering several boreholes within the ash disposal area for the purpose of obtaining near-continuous samples of fly ash for density determinations. Standpipe-type piezometers were installed near the bottom of each borehole for the purpose of monitoring water level fluctuations within the ash mound. A total of seven boreholes were augered into the fly ash and their locations are indicated in Figure 1. Fly ash samples were collected from boreholes #1, 2, 3, 4 and 7. Piezometers were installed in all seven boreholes. Ground elevations and ash/clay contact elevations are listed in Table I.

Fly ash samples for density measurements were collected in two different ways: i) above the water table, 5 cm diameter Shelby tubes proved satisfactory for collecting fly ash; ii) below the water table, a 1.5 m long (1.5 m) piston sampler rented from Solinst of Glen Williams, Ontario, provided satisfactory sample recovery.

The piston sampler, also termed the Saturated Sand Sampler, consists of a steel core barrel with a hardened drive shoe, a piston, a wireline retrieval system and inner liners dedicated to each sample. The liners used for this project were 1.5 m long, 5 cm in diameter and made of clear PVC. To obtain a continuous sample, the core barrel, with the piston placed at the leading edge, is attached to drill rods and lowered to the bottom of the borehole. The piston is then held stationary by the wireline as the sampler is driven into the undisturbed material. The suction developed by the relative movement between the core barrel and the piston is generally sufficient to obtain good sample recovery and retention of pore fluids.

Once the sampler has been returned to the ground surface, the sample-filled liner is removed from the core barrel and capped to prevent sample disturbance and moisture loss. Simple recovery using the piston sampler below the water table was in general greater than 80%. Both the piston sampler and Shelby tubes were used to obtain ash samples above the water table, however, recoveries were generally less than 80%.

Poor sample recovery can in part be attributed to plugging of the sampler. As soil enters the sampling tube, friction gradually builds up between the sample and the inner wall of the tube. If the magnitude of this internal friction exceeds the bearing capacity of the soil being sampled, the sampler will continue to advance but no further soil will enter the tube. If the bearing capacity of the soil happens to increase within the sampling interval, the internal friction within the sampler may be exceeded and soil will once again enter the sampler. Under this scenario, disturbed soil is being sampled and consequently any testing of the sample may lead to erroneous results. An example of this would be the densification of loose material ahead of the penetrating sampler, which would lead to higher than normal measurements of density. At present, there is no method available to help differentiate between plugging of the sampler or simple loss of sample during retrieval.

3.0 RESULTS OF FIELD AND LABORATORY WORK

The results of the field and laboratory work will be outlined in two subsections dealing with fly ash density profiles and water level measurements respectively. A third subsection will deal with the implications of these new data on the stability analyses conducted previously.

3.1 Fly Ash Density Profiles

The results of ash sampling and density measurements are provided in Figure 2. Density values were obtained by weighing the sample-filled tubes, subtracting the weight of the tube and dividing by the known volume of sample. This is termed a measurement of bulk density which includes the weight of solids and porewater. In the case of borehole #7, a more detailed profile was obtained by cutting the ash samples into one or two-foot lengths prior to measuring density.

The bulk densities of the fly ash sampled from boreholes #1, 2, 3, 4 and 7 range between 1120 and 1760 kg/m^3 (70 and 110 pcf). The average value is equal to 1440 kg/m^3 (90 pcf).

The variability in the density profiles may be attributed in part to the changing specific gravity of fly ash throughout the operating history of the station. Large variations in compactive effort and initial moisture contents during placement of the ash may have also lead to the non-uniformity in density profiles. The variability in fly ash strength within the mound was first observed in the results of piezocone soundings reported previously/1/.

Several weak zones were noted during the sampling operation. The following weak zones were exemplified by low penetration resistances and very poor sample recovery even with the piston sampler: i) at borehole #2, between 3 and 4.6 m below ground level; ii) at borehole #4, between 4.6 and 6 m BGL.

The dry density profile plotted for borehole #7 is an indication of the actual mass of fly ash per unit volume. The dry densities vary between 800 and 1120 kg/m^3 (50 and 70 pcf) and show a general trend of increasing densities with depth. A 0.9 to 1.2 m thick, low density layer was observed near the bottom of the borehole.

It is interesting to note that the standard Proctor compaction test on fly ash yields a maximum dry density of 1250 kg/m^3 (78 pcf) at approximately 29% moisture content. At the Canada Brick fly ash disposal site located in Mississauga, Ontario, dry densities on the order of 90% Proctor maximum, or 1120 pcf (70 pcf), were readily achievable with Lakeview TGS fly ash under controlled compaction and moisture conditions/2/. It is evident from the dry density profile of borehole #7 in Figure 2, that a significant volume of fly ash has been placed at a dry density below 1120 kg/m^3 (70 pcf). Better control over compactive effort and placement moisture content could have ensured a more consistent dry density of between 960 and 1040 kg/m^3 (60 and 65 pcf), which could have helped to increase the storage capacity of the site. Disposal practices at future fly ash and/or FGD waste sites should consider proper compaction control to help maximize the use of the available storage area.

3.2 Water Level Measurement

Water level readings in all 7 piezometers have been obtained by station personnel since early June. Water levels measured on July 20, 1990, are provided in Table I along with other pertinent elevation data. Periodic monitoring should continue in an effort to observe any seasonal trends in water table position.

Based on the water level data collected to date, the following observations can be made:

1) Water levels in the ash are highest in the southeast quadrant of the disposal area and decrease towards the west and northwest, in the direction of Lake Lambton.

2) The water levels in piezometers #4 and #5 reflect the elevation of water in Lake Lambton. The water level of Lake Lambton has increased by approximately 0.5 m (1.6 ft) since 1987, as shown in Figure #1. Exactly when this increase occurred is presently unknown, however, it would have caused additional erosion of ash along the shore of Lake Lambton.

3) The water level in piezometer #1 is a reflection of the proximity of drainage boundaries such as Lake Lambton and the internal ash slope immediately to the west. The toe of this ash slope is at approximately 190 m ASL and therefore, any water accumulating in the ash above that elevation would have a tendency to drain towards the slope. If drainage would somehow be inhibited in this direction, the internal water pressure within the ash slope could increase sufficiently to cause local slumping failure near the toe of the slope.

4) The water levels recorded in piezometers #2, #3 and #6 are all at a higher elevation than the top of the clay dyke along the southeast edge of the ash disposal area. This is due to continuous infiltration of water into the ash and the long drainage path towards Lake Lambton. The top of the clay dyke, which corresponds with the toe of the ash slope, is at an approximate elevation 193.5 m ASL along the southeast portion of the perimeter. Based on data provided in Table I, the water levels in the vicinity of piezometers #2, 3 and 6 are 1.4, 0.4 and 1.2 m above the toe of the ash slope. Consequently, not only is the water from this area draining towards Lake Lambton, it is also draining towards the adjacent ash slopes. As water exits above the toe of the slope, local instability and slumping failure can be expected to occur as discussed in a previous report/1/.

The consequences of seepage from the ash slope along the southeast perimeter of the disposal area have been the following:

1) Several small slump failures occurred along the south ash slopes in early summer before and during the field work for this investigation. The failures were probably caused by the steep slope of the ash (>2:1), the high water level and by the close passage of large haulage trucks transporting clay towards the far eastern portion of the area. Vibrations produced by these trucks may have triggered the shallow failures. These failures were characterized by complete liquefaction of the saturated ash at the toe of the slope, causing the fluidized material to partially overtop the surrounding clay dyke. Evidence of the high internal water level was clearly observed along the scarp face produced by the failures.

2) Shallow failures have not occurred along the eastern edge of the disposal area due, in part, to the relative inactivity in this area and to the flatter slope angle (3:1). However, evidence of seepage is found in the form of healthy marsh vegetation growing along the top of the clay dyke at numerous locations. These marshy areas remain saturated even after prolonged dry periods.

Figure 3 presents results of water level monitoring in the seven piezometers throughout the summer of 1990. As mentioned previously, levels in piezometers #4 and #5 reflect the water level of Lake Lambton. As such, the water level of Lake Lambton rose by approximately 20 cm between mid-August and mid-September. Surprisingly, water levels in piezometers #2, #3 and #6 also increased throughout the same period by 20, 15 and 10 cm respectively. Piezometers #1 and #7, both located within the higher, central portion of the ash disposal area, remained relatively stable between August and September. The dramatic mid-August drop in water level of piezometer #7 is presently considered anomalous.

3.3 Review of Previous Stability Analyses

One of the objectives of this year's field program was to confirm some of the assumptions made, with respect to material properties and water levels, during the previous slope stability analyses/1/. One of the most important assumptions concerned the magnitude of the ash bulk density which was assumed to be 1440 kg/m^3 (90 pcf). In reviewing the density profile data collected this year, it was concluded that the average bulk density was indeed close to 1440 kg/m^3. It must be emphasized that this is an average value and not a maximum value. Therefore, the safety factors calculated from the previous stability analyses (FS = 1.16 to 1.26) were not overly conservative.

The water within the ash mound was assumed to be at a height corresponding to 50% of the total ash height at the centre of the mound and decrease linearly towards the toe of the ash slopes. From the monitoring of piezometric levels within the ash disposal area, this previous assumption was not entirely valid. However, the position of the water table within the ash did not play a significant role in determining the overall stability of the mound/1/. Of greater importance was the position of the water table at the toe of the ash slopes.

Previous stability analyses predicted that shallow slump failures would occur (factor of safety < 1.0) if the internal water table exited 2.0 metres above the toe of a 2.5:1 ash slope. As reported previously, slump failure did occur along the southeast corner of the ash disposal area where slope angles range from 1.7:1 to 2.0:1. The position of the internal water table in this area was determined by the thickness of saturated ash along the scarp face left by the failures. The position of the water table was approximated at 1.8 m above the top of the clay dyke.

4.0 RECOMMENDATIONS

1. The results of the field work confirm the ash density value used in previous stability calculations. In view of this, it is recommended that all external ash slopes be maintained at 3 to 1 and properly vegetated to reduce erosion. This will provide short-term stability of the ash slopes against slumping failure and long-term stability of the ash storage area as the top surface reaches a maximum elevation of 203 metres.

2. The effect of the position of the water table on the local stability of external slopes was dramatically demonstrated by the shallow failures which occurred in early summer. The stability of the external ash slope in the southeast corner of the ash mound could be increased by ensuring that the slope angle is maintained at 3 to 1. In addition, some effort should be made to control the rise of the internal water table in this area. This could be accomplished locally by installing horizontal drains, of an appropriate size and spacing, into the ash mound at the level of the crest of the clay dyke. The practice of placing clay covers over the ash slope will not prevent the internal water level from rising. Eventually, the water will percolate through the clay veneer resulting in renewed instability. The purpose of a clay cover on an ash slope should be to reduce dusting problems and eliminate erosion of the ash by water runoff.

3. Based on preliminary monitoring, there appears to be some relationship between fluctuations in the level of Lake Lambton and fluctuations in the internal water table in the southeast quadrant of the ash mound. Periodic monitoring of piezometer water levels should continue to help confirm this relationship. Water level measurements obtained every 2 to 3 weeks should provide satisfactory data, however, more frequent readings should be made during periods of continued rainfall or during rapid fluctuations in the level of Lake Lambton.

4. Significant erosion of ash has occurred along the south shore of Lake Lambton due to wave action. This has lead to local instability along the shoreline and has probably reduced the depth of the lake as eroded ash settles along the bottom. This problem could be alleviated by the placement of large cement or lime-stabilized fly ash blocks along critical portions of the shoreline. This procedure is similar to standard shoreline protection methods utilized for natural lakes except that material costs are greatly reduced by making use of existing fly ash in the manufacture of the blocks.

5. Ash storage could be increased at this site by partially filling in Lake Lambton. Alternatively, the stability of the entire flat area south of Lake Lambton could be improved by strengthening of the underlying ash using lime injection techniques. The potential strength improvement could make this unused area available for ash storage. This option would have to be investigated closely to prove its technical and economical viability.

6. The placement of clay as a temporary cover for the ash mound should be used judiciously. Once the placement of ash is renewed, appropriate drainage of infiltrating water must be insured to prevent the creation of a perched water table condition. This condition could lead to instability as water migrates along the top of the internal clay layer towards the external ash slope.

Approved by:

T.W. Klym
Manager
Civil Research Department

Prepared by:

A. Vorauer
Engineer
Soil Sciences Section

Reviewed by:

C.B.H. Cragg
Senior Engineer
Soil Sciences Section

AV:LM

REFERENCES

1. Vorauer, A. "Lambton TGS Ash Storage Area - Stability Analysis". Research Division Report No 89-314-K, 1990.

2. Golder Associates. "Review of Compaction Control Data, Domtar Quarry Reclamation, Mississauga". #811-1323, 1982

TABLE I

ELEVATION DATA FROM BOREHOLES AUGERED AT LAMBTON TGS ASH STORAGE AREA

Borehole Number	Ground Elevation (m.ASL)	Top of Piezometer (m.ASL)	Ash/Clay Contact (m.ASL)	Water Level July 20/90 (m.ASL)
1	202.95	203.92	185.42	190.63
2	198.19	199.02	187.98	194.90
3	197.79	198.63	188.74	193.90
4	194.65	195.13	186.20	189.98
5	192.43	193.39	186.94	189.94
6	200.58	201.29	-	194.74
7	203.43	204.36	-	193.29
LAKE LAMBTON	-	-	-	189.97

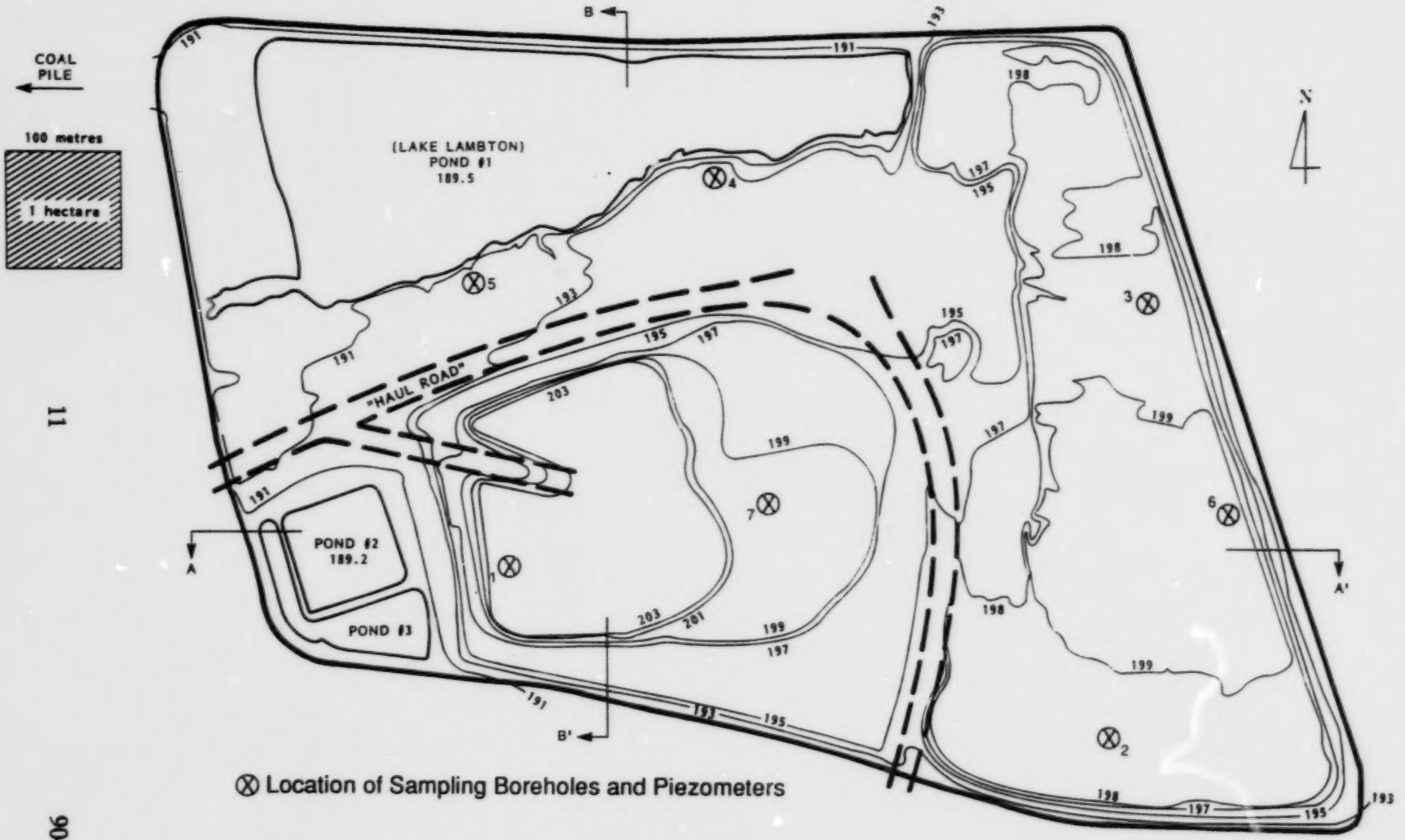

FIGURE 1

ASH STORAGE AREA CONTOUR PLAN 1987

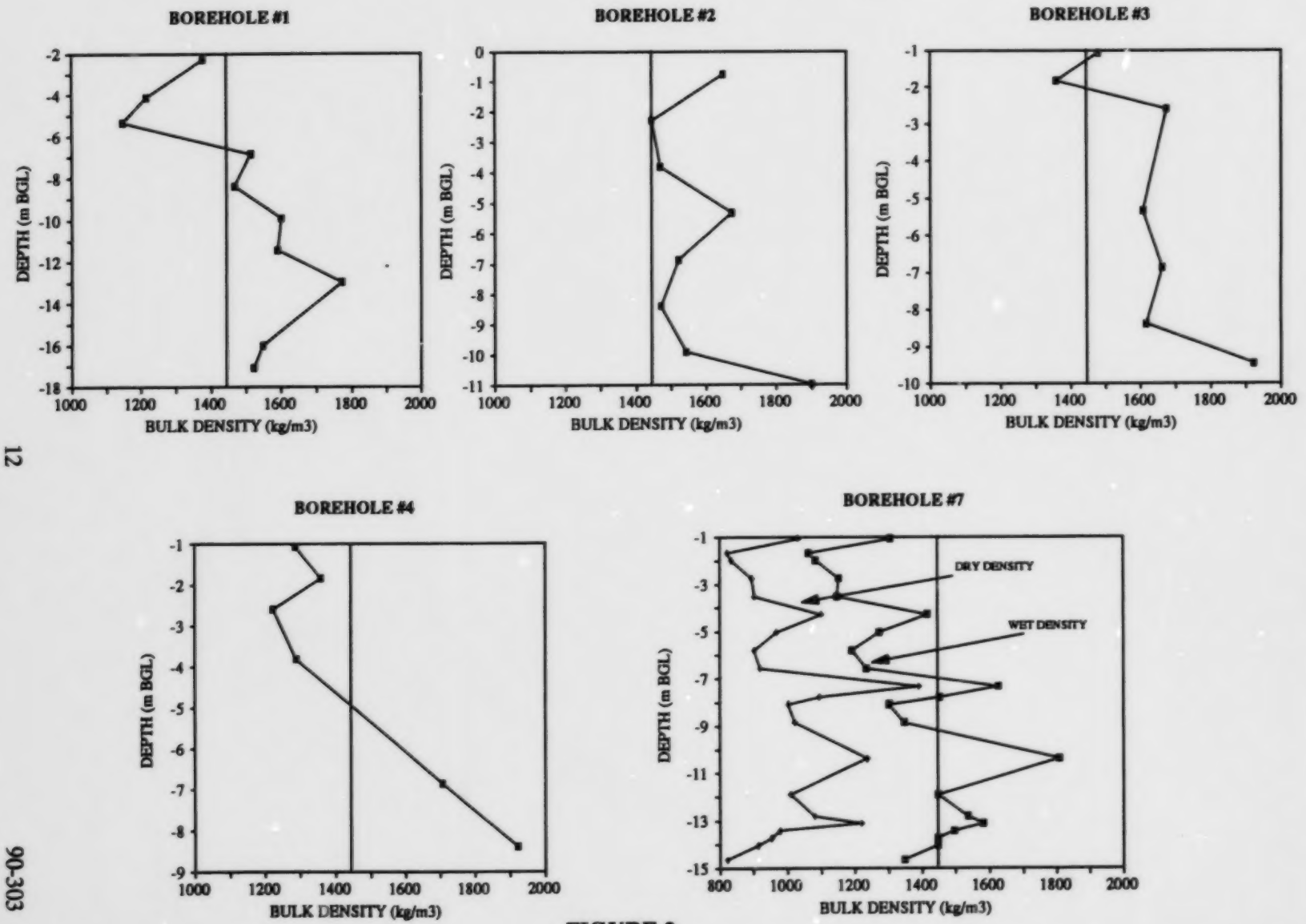

FIGURE 2

Density profiles at Lambton TGS fly ash disposal area

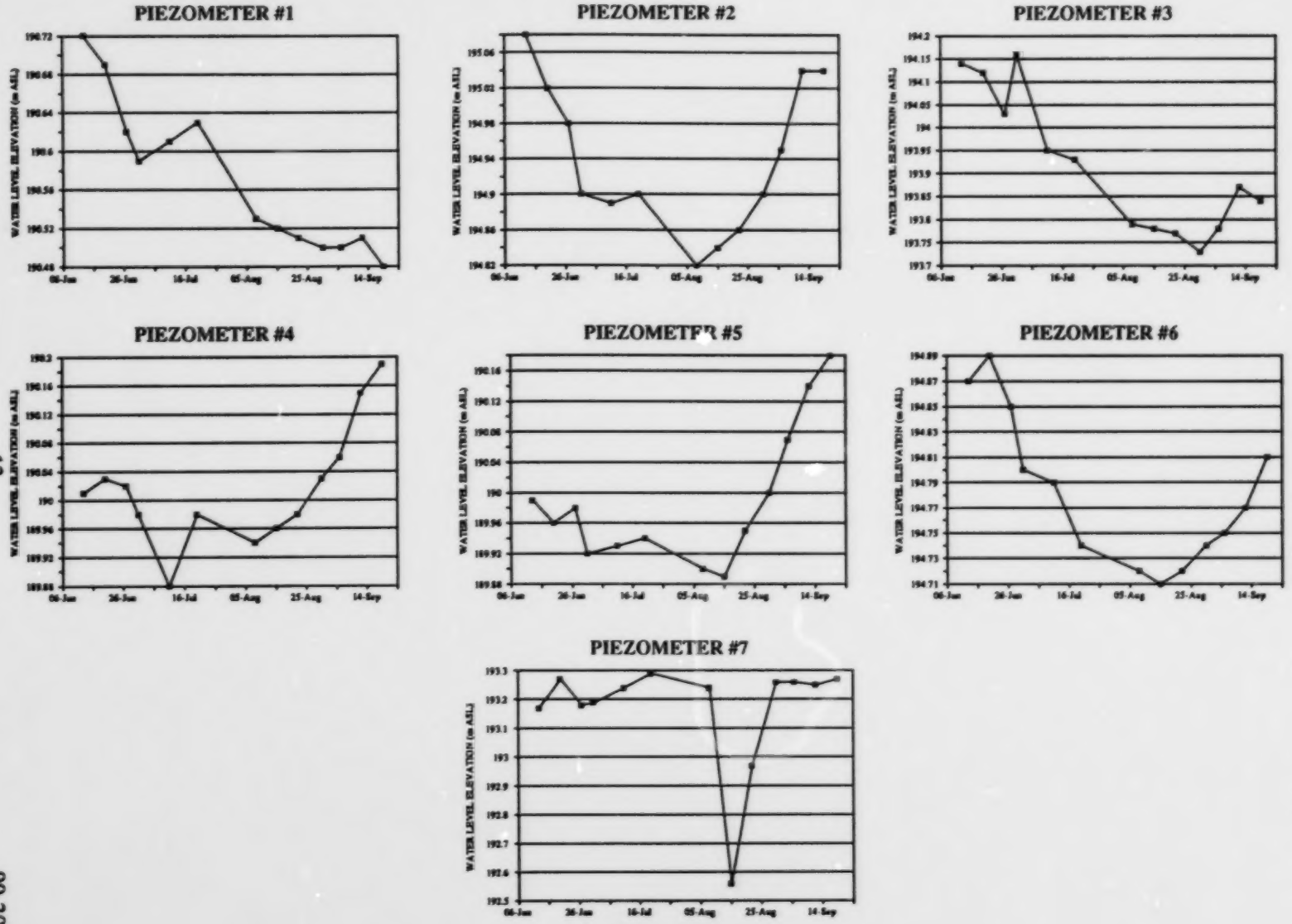

FIGURE 3
Water level fluctuations within Lambton TGS ash disposal area